G2CD: Software Digitizer For High Granular Gaseous Detector

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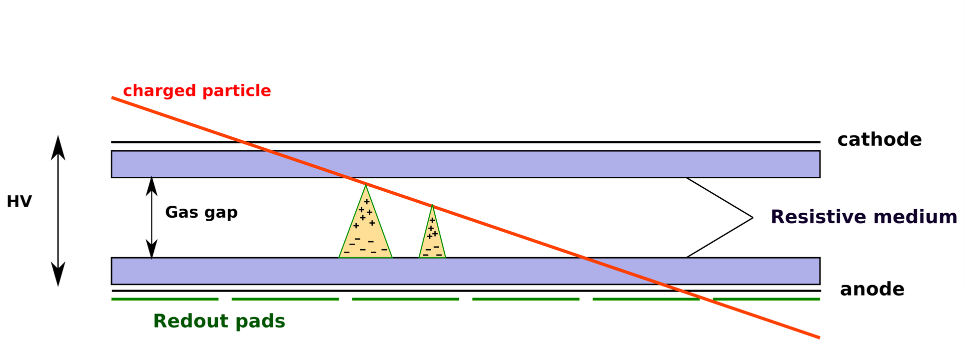
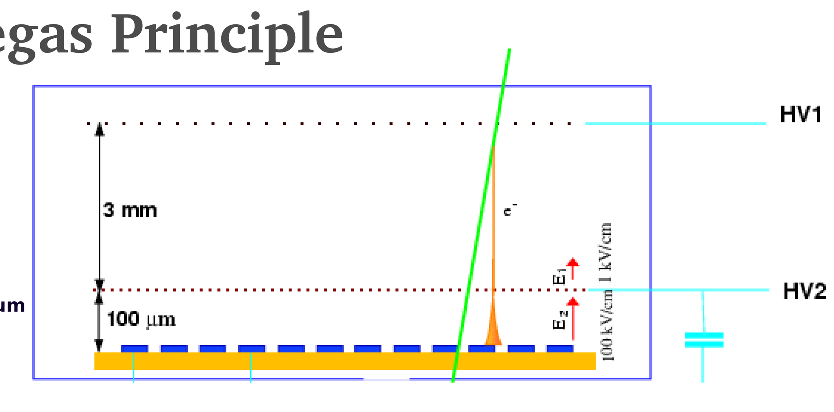
Simulation of the pad response in a gaseous detector in binary readout

A sampling calorimeter equipped of gaseous sensor layers with digital readout is near perfect for Particle Flow [1][2] analysis, since it is homogeneous, robust, cost efficient, easily segmentable to any pad dimension and size and almost insensitive to neutrons. The response of a digital calorimeter is characterized by its efficiency and multiplicity. To complete the simulation tool and to make possible a simulation based analysis as well as data-Monte-Carlo comparison, we developed a general method for simulating the pad response, a digitization, reproducing efficiency and multiplicity. It uses the spatial information from a simulation done at higher granularity. This method can be applied to various types of gaseous detectors including GRPC and MicroMegas. Validating the method on test beam data, experimental observables such as efficiency, multiplicity and number of hits at different thresholds have been reproduced to high precision.

RPC & MicroMegas Principle





- **Glass Resistive Plate Chamber (GRPC) [3]**
  - Passage of a charged particle ionizes the gas
  - Principle: Towsend avalanche (drift + amplification in the same gas gap)
  - The charge movement induces a charge on the readout pad → Signal
- Gas: TFE/CO2/SF6 (93/5/2 %)
- Readout pads 1×1 cm^2

- **MicroMegas (µM) [5]**
  - Passage of charged particles ionizes the gas
  - Drift & amplification in two different zones
  - The charge induced in readout pad → Signal
- Gas: Ar/CO2 (80/20 %)
- Readout pads 1×1 cm^2

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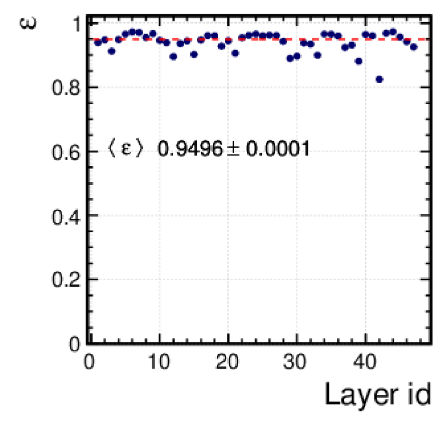
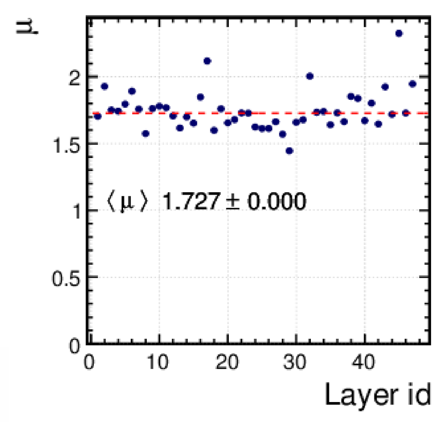
Induced Charge Measurement using Mip's

- The SDHCAL prototype [3] is a digital calorimeter with 50 GRPC sensor layers of 1m^2 each separated by a gap of 2.8cm
- Muons do not interact in the calorimeter providing minimum ionizing particles (MIP) → appropriate for GRPC characterization
- Muons observed in the SDHCAL prototype were used for this GRPC study, they were taken during SDHCAL test Beam periods @ CERN.

- **Muon reconstruction flow in a few steps:**
  - Hits clustering in each layer using nearest neighbor clustering
  - Center of gravity of hits on each cluster ⇒ The position of cluster
  - Isolated hits are dropped
  - Track reconstruction based on χ^2 minimization



- **The Efficiency and multiplicity estimation :**
  - Efficiency (ε) = presence of at least one hit within 2 cm around the projected impact point
  - Multiplicity (µ) = number of hits in each plate
  - This estimation is done for each layer using the clusters of other layers to define the track



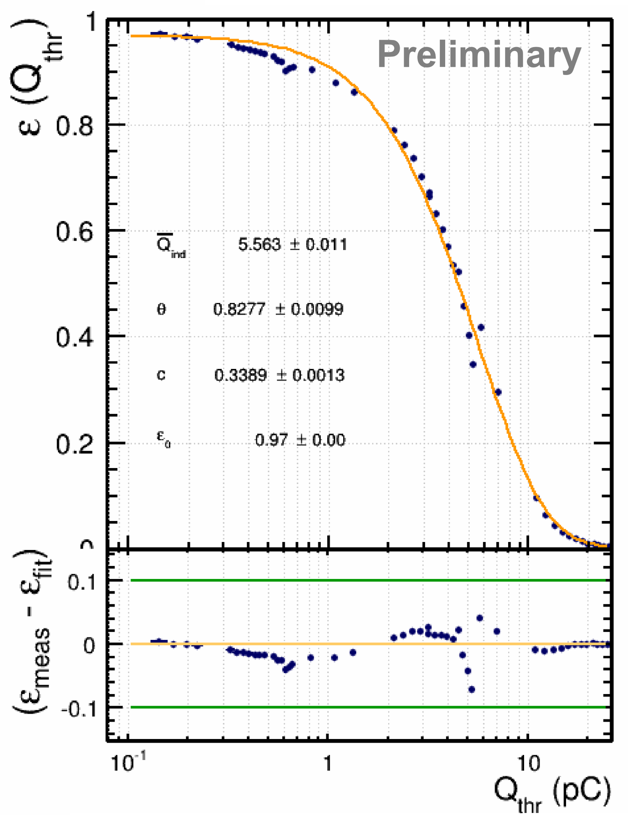
- **Charge Spectrum measurement:**
  - The induced charge in RPC follows the Polya [4] distribution defiled by:

$$P(q;\theta,\overline{q})=\left(q\frac{(1+\theta)}{\overline{q}}\right)^{\theta}exp\left\{-q\frac{(1+\theta)}{\overline{q}}\right\}$$

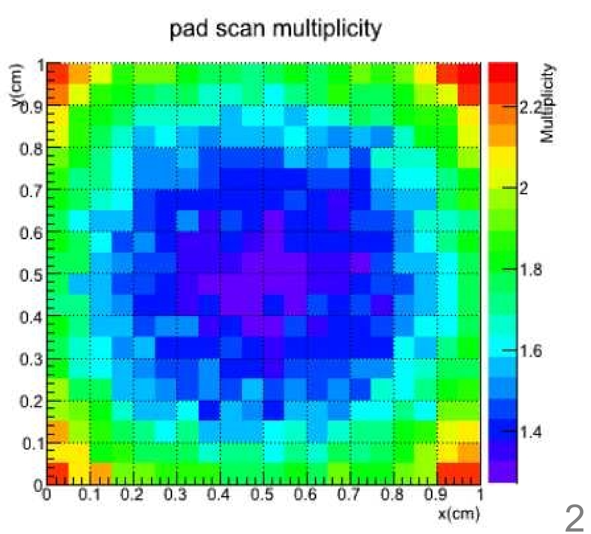
  - = mean charge, θ = width
  - Measurement of ε vs threshold value → integration of the charge spectrum:

$$\varepsilon(q_{thr})=\varepsilon_0-c\int_0^{Q_{thr}}p(q;\theta,\overline{q})\,dq$$

  - ε_0 = efficiency at 0pC → dead zones
  - c = normalization constant



- **Multiplicity map in cell:**
  - The mean multiplicity as a function of the reconstructed muon position in the cell
  - Charge image size: to reproduce the multiplicity → need position information in millimeter precision



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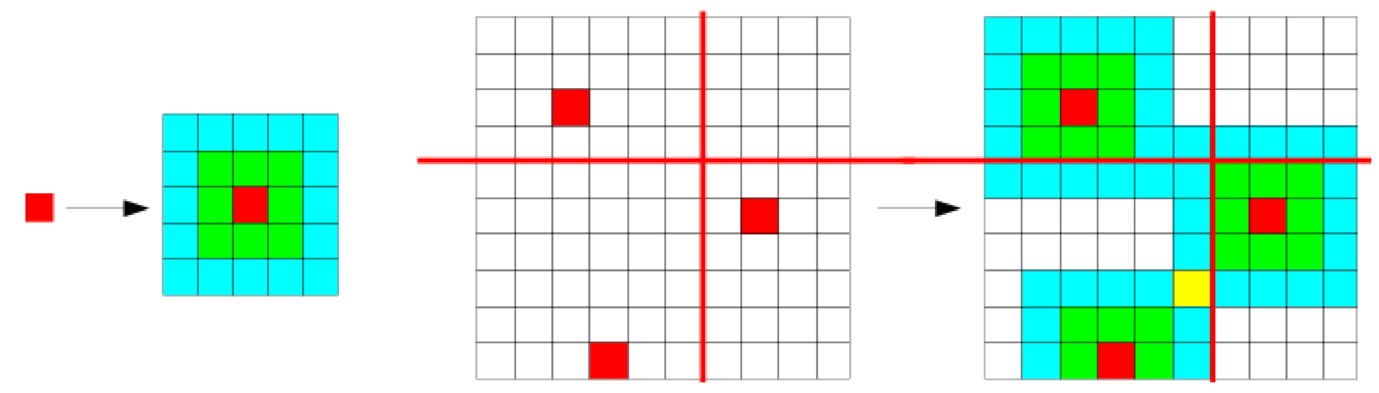
Digitization approaches

Standard Analogue Approach:

- The fraction of the charge induced on each pad is inferred from the 2D integration of a known profile and the precise position of the GEANT4 hit.
- The value of the induced charge is drawn randomly following a Polya distribution [4] with parameters estimated from data.
- The charge profile is tuned to reproduce ε and µ on the data
- This methods requires the storage of each GEANT4 hit if post-processing is needed

Small cell Approach (G2CD):

- parametrize 1mm simulated hit with:
  - Induced charge from Polya distribution
  - Charge distribution table
- Accumulate charge within targeted area ~ digitized hit (10×10 mm)
- No need to store individual hits → better suited for linear collider detectors optimization studies (variable size of cells, geometry …)



Simulated hit → charge spatial table → charge accumulation → apply the threshold

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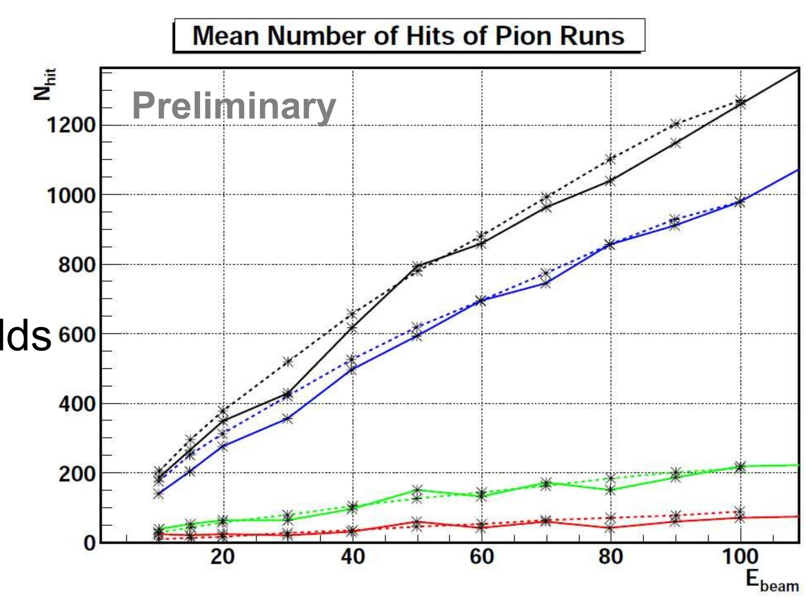
G2CD Results

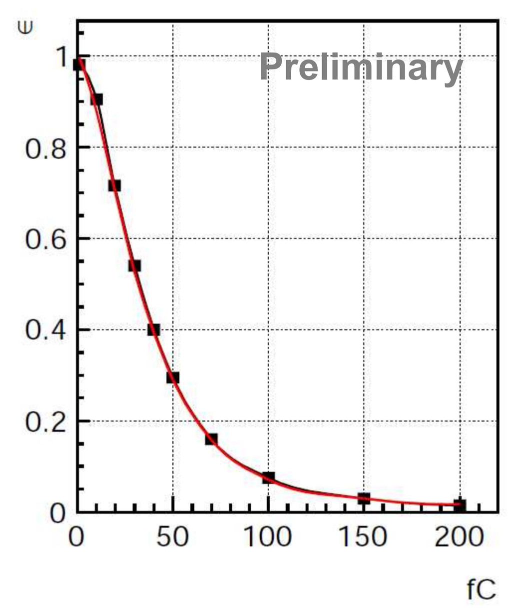
Digitizer results for GRPC-SDHCAL:

- Multiplicity for hadronic showers
- Solid curves → data
- Dashed curves → Simulation+Digitization
- The colors correspond to different thresholds

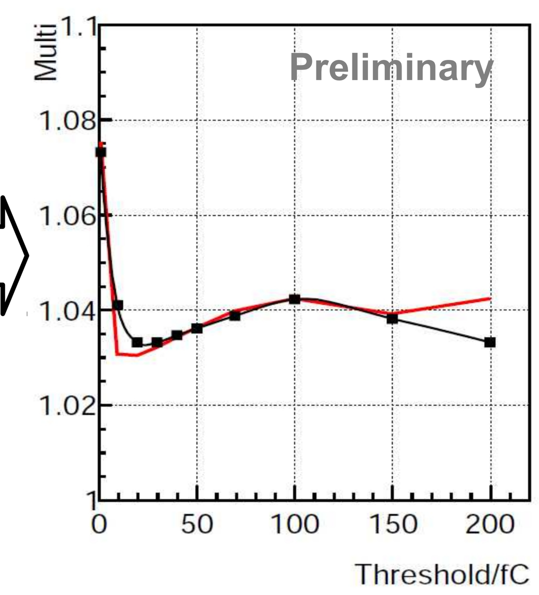


Digitizer results for µM:

- Data taken in 2009 [5]



Threshold scan for µM



Reproduced multiplicity with threshold

Good correspondence between the measured multiplicity (black curve) & Simulation+Digitizer (red curve)

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Conclusion

- Two gaseous detector digitizations were developed for the SDHCAL prototype: an analogue and a digital (G2CD)
- G2CD offers more flexibility in optimization studies
- It was tested with good agreement data/simulation for µM and GRPC sensors with muons in linear collider hadronic calorimeter prototypes

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References :

[1] - Mark A. Thomson , Particle flow calorimetry,J.Phys.Conf.Ser. 293 (2011) 012021
[2] - Jean-Claude Brient, Henri Videau, The Calorimetry at the future e+ e- linear collider SNOWMASS-2001-E3047, e-Print: hep-ex/0202004
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[4] - H. Genz, Nucl. Instr. and Meth. 112 (1973) 83–90.
[5] - C.Adloff, et al, MICROMEGAS chambers for hadronic calorimeter, 2009, JINST 4 P10008